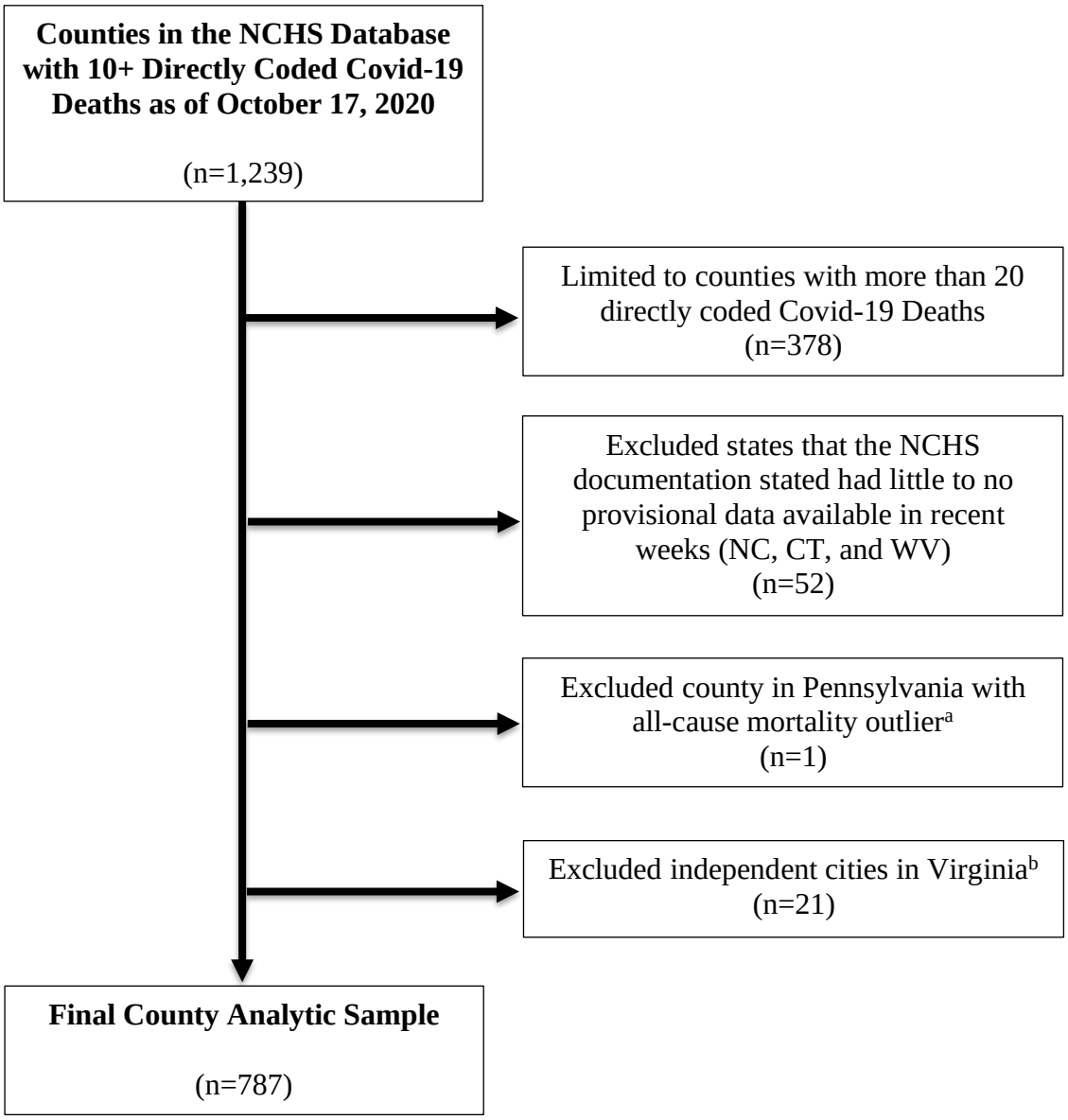
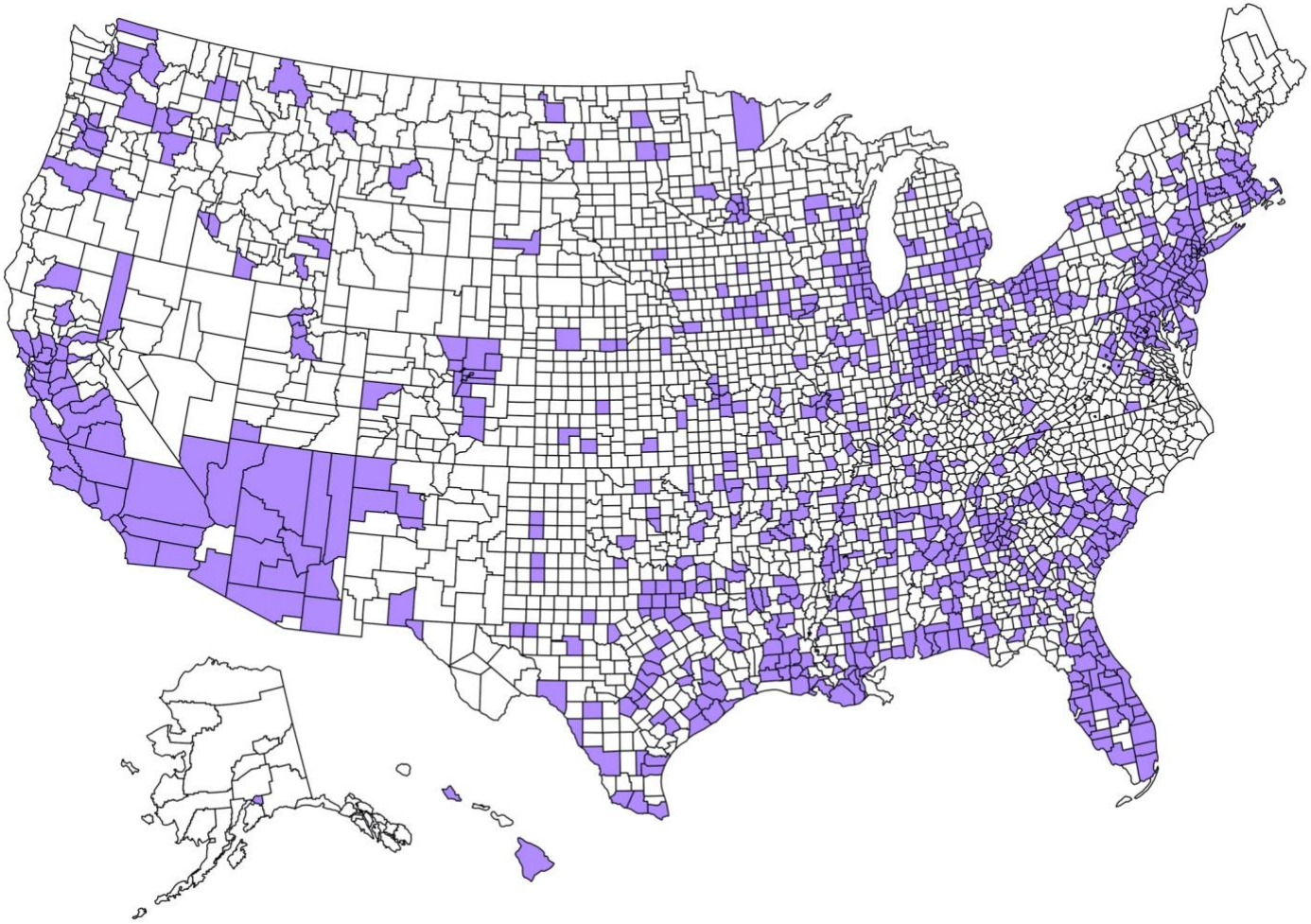
Supplementary Material

Figure S1: Flowchart Detailing Sample Exclusions



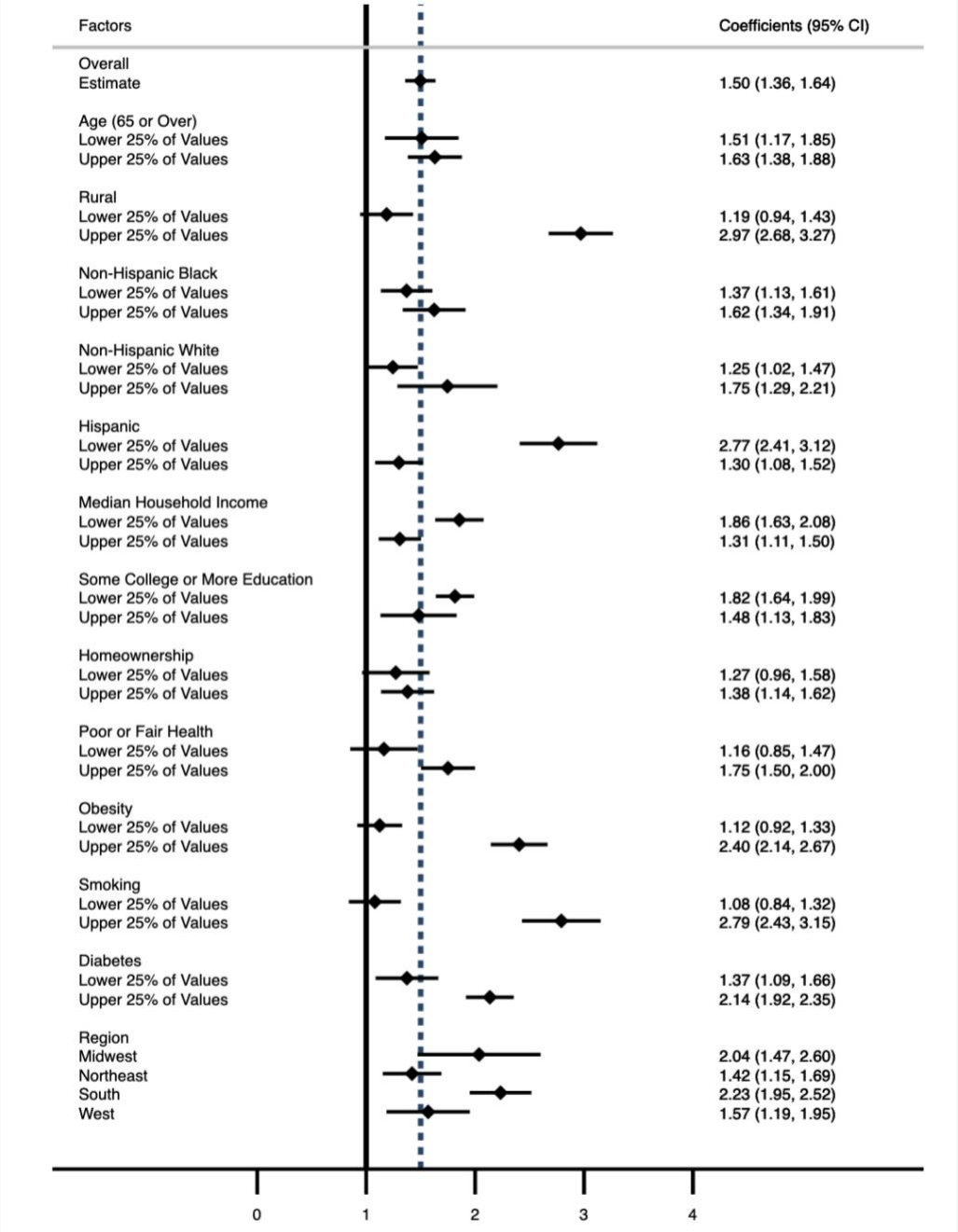
a. All-cause mortality in this county was more than 200% greater than the county with the next highest all-cause mortality.
b. We chose not to incorporate independent cities into neighboring counties because several of the neighboring counties were not included in the 1,239 counties represented in the dataset.

Figure S2: US County Map Showing Geographic Distribution of Sample Counties (n=787)[a]



a. Map created using the usmap package in RStudio (https://CRAN.R-project.org/package=usmap)

Figure S3. Relationship Between Indirectly Age Standardized All-Cause and Direct Covid-19 Mortality across Strata of Sociodemographic and Health Factors[a,b,c]

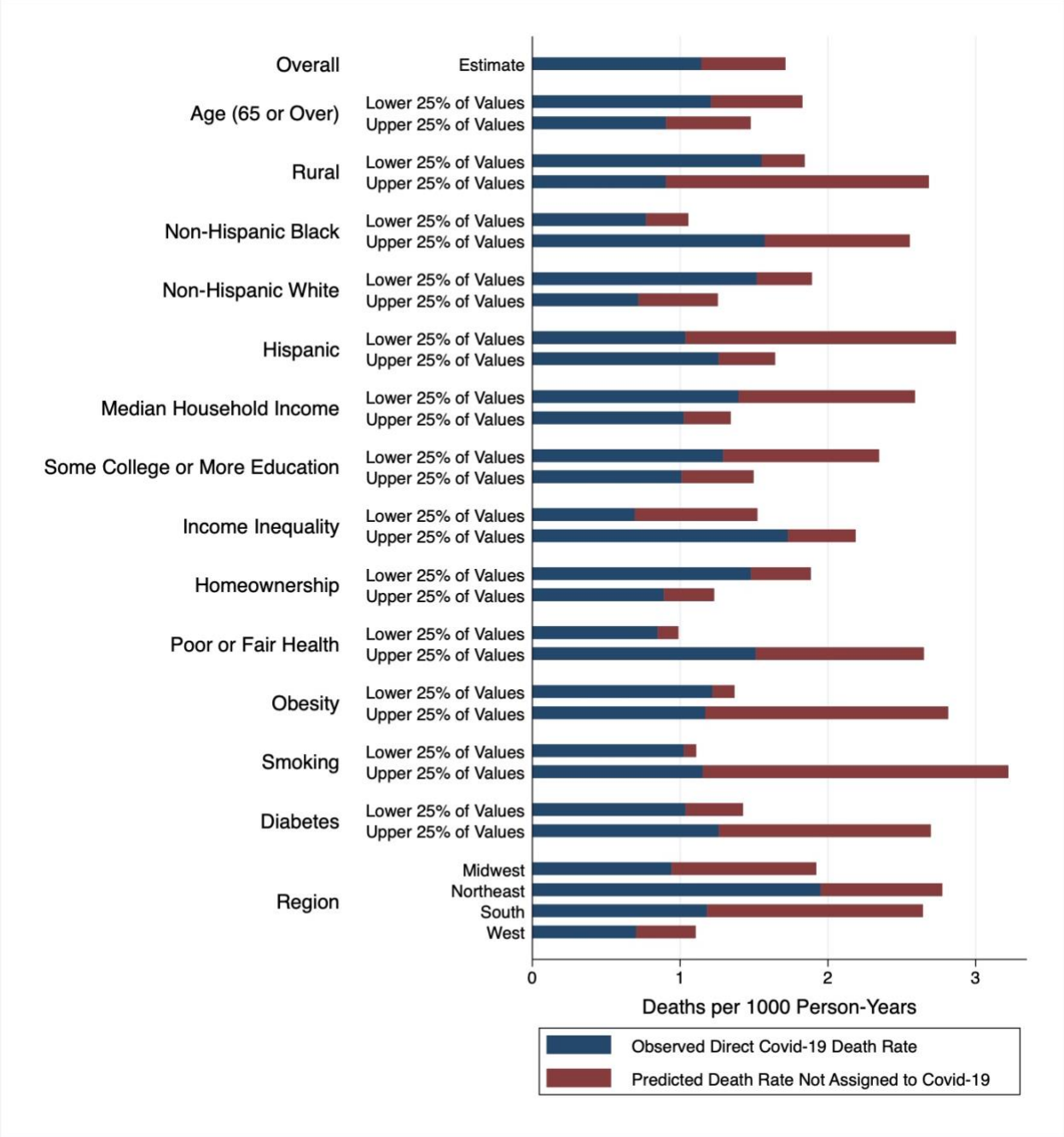


a. n = 787 counties

b. β_2 coefficients generated from primary model: $M(i) = \alpha + \beta_1 M^*(i) + \beta_2 C(i)$, where $M(i)$ = Death rate from all causes in county i in 2020, $M^*(i)$ = Death rate from all causes, county i in 2013-2018, and $C(i)$ = Covid-19 death rate in county i in 2020. The model was weighted by the 2020 population and fully stratified into population weighted quartiles for each sociodemographic or health factor. The coefficients for the upper and lower 25% of values for each factor are presented in this figure.

c. Sample interpretation: in counties with lower household income, for every 1 directly assigned Covid-19 death, there was an increase in 1.86 all-cause deaths, suggesting there were 0.86 deaths not assigned to Covid-19 for every 1 directly assigned Covid-19 death in these counties.

Figure S4. Decomposition of 2020 Indirectly Age Standardized Excess Death Rates across Strata of Sociodemographic and Health Factors[a,b]



a. n = 787 counties

b. Predicted death rates generated from primary model: $M(i) = \alpha + \beta_1 M^*(i) + \beta_2 C(i)$, where $M(i)$ = Death rate from all causes in county i in 2020, $M^*(i)$ = Death rate from all causes, county i in 2013-2018, and $C(i)$ = Covid-19 death rate in county i in 2020. The model was weighted by the 2020 population and fully stratified into population weighted quartiles for each sociodemographic or health factor. The death rates for the upper and lower 25% of values for each factor are presented in this figure.

Table S1. Data Sources and Years for County-Level Factors

Variable	**Data Source:**
% 65 Years and Older	Census Population Estimates, 2018
% Rural	Census Population Estimates, 2010
% Hispanic	Census Population Estimates, 2018
% Non-Hispanic Black	Census Population Estimates, 2018
% Non-Hispanic White	Census Population Estimates, 2018
Median Household Income	Small Area Income and Poverty Estimates, 2018
% with Some College or Higher	American Community Survey, 5-year estimates, 2014-2018
Income Inequality	American Community Survey, 5-year estimates, 2014-2018
% Homeownership	American Community Survey, 5-year estimates, 2014-2018
% with Poor or Fair Health	Behavioral Risk Factor Surveillance System, 2017
% with Obesity	United States Diabetes Surveillance System, 2016
% who Smoke	Behavioral Risk Factor Surveillance System, 2017
% with Diabetes	United States Diabetes Surveillance System, 2016

Table S2. Comparison of OLS, Indirectly Age Standardized and Negative Binomial Models

Model	Number of Excess Deaths per 1 Directly Coded Covid-19 Death	% Excess Deaths Not Attributed to Covid-19
OLS Model[a,b]	1.44 [95% CI (1.30, 1.59)]	30.7% [95% CI (23.8%, 37.5%)]
OLS Model, Age-Standardized[a,b,c]	1.50 [95% CI (1.36, 1.64)]	33.2% [95% CI (27.0%, 39.4%)]
Negative Binomial Model[d,e]	1.45	30.9%

a. The OLS models were specified as $M(i) = \alpha + \beta_1 M^*(i) + \beta_2 C(i)$, where $M(i)$ = Death rate from all causes in county i in 2020, $M^*(i)$ = Death rate from all causes, county i in 2013-2018, and $C(i)$ = Covid-19 death rate in county i in 2020. Model weighted by the 2020 population. For the Negative Binomial model, $M(i) =$ deaths from all-causes in county i in 2020 rather than the death rate, with the 2020 population used as an offset.

b. Number of excess deaths per 1 directly coded Covid-19 death is equivalent to the regression coefficient for directly coded Covid-19 deaths.

c. Death rates were indirectly age-standardized.

d. To calculate the number of excess deaths per 1 directly coded Covid-19 deaths, we used marginal prediction to calculate the all-cause death rate in 2020 at values of directly coded Covid-19 mortality that were +/- 0.1 deaths per 1000 people from the weighted mean of directly coded Covid-19 mortality. The change in all-cause mortality between these values was divided by 0.2 deaths per 1000 people to yield the number of excess deaths per 1 directly coded Covid-19 death.

e. A Poisson model was tested prior to the Negative Binomial model but was rejected due to poor goodness of fit.

Table S3. Risk Ratios for 2020 Excess Death Rates across Strata of Sociodemographic and Health Factors[a,b]

Factors	Comparison Group	Risk Ratios for Crude Covid-19 Death Rates[c]		Risk Ratios for Indirectly Age Standardized Covid-19 Death Rates[d]	
		Direct Covid-19 Death Rate	Predicted Excess Death Rate[e]	Direct Covid-19 Death Rate	Predicted Excess Death Rate[e]
Age (65 or Over)	Upper vs. Lower	1.20	1.22	0.75	0.81
Diabetes	Upper vs. Lower	1.29	2.43	1.22	1.89
Hispanic	Upper vs. Lower	1.00	0.52	1.22	0.57
Homeownership	Upper vs. Lower	0.74	0.91	0.60	0.65
Income Inequality	Upper vs. Lower	2.52	1.56	2.49	1.44
Median Household Income	Upper vs. Lower	0.77	0.54	0.74	0.52
Non-Hispanic Black	Upper vs. Lower	1.93	2.18	2.04	2.42
Non-Hispanic White	Upper vs. Lower	0.60	0.71	0.47	0.66
Obesity	Upper vs. Lower	0.91	2.25	0.96	2.06
Poor or Fair Health	Upper vs. Lower	1.59	2.65	1.78	2.68
Region	Midwest vs. West	1.49	1.58	1.34	1.74
Region	Northeast vs. West	3.24	2.02	2.77	2.51
Region	South vs. West	1.73	2.34	1.68	2.39
Rural	Upper vs. Lower	0.61	1.52	0.58	1.46
Smoking	Upper vs. Lower	1.11	2.64	1.12	2.91
Some College or More Education	Upper vs. Lower	0.81	0.52	0.78	0.64

a. n = 787 counties

b. Predicted death rates generated from primary model: $M(i) = \alpha + \beta_1 M^*(i) + \beta_2 C(i)$, where $M(i)$ = Death rate from all causes in county i in 2020, $M^*(i)$ = Death rate from all causes, county i in 2013-2018, and $C(i)$ = Covid-19 death rate in county i in 2020. The model was weighted by the 2020 population and fully stratified into population weighted quartiles for each sociodemographic or health factor. A risk ratio of death rates was then calculated comparing the two strata (i.e. upper 25% vs. lower 25% income inequality).

c. Calculated using the decomposed death rates presented in Figure 3.

d. Calculated using the decomposed death rates presented in Supplemental Figure 4.

e. Predicted excess death rate includes (1) the observed direct Covid-19 death rate and (2) the predicted excess death rate not assigned to Covid-19. The predicted excess death rate was calculated by multiplying the mean observed direct Covid-19 mortality for the stratum by its β_2 coefficient.